

# MOBILE STATION SYNCHRONIZATION WITHIN A SPREAD SPECTRUM COMMUNICATION SYSTEMS

## BACKGROUND OF THE INVENTION

### 1. Technical Field of the Invention

The present invention relates to spread spectrum communications systems and, in particular, to timing synchronization of a mobile station with a base station in a spread spectrum communications system.

### 2. Description of Related Art

The cellular telephone industry has made phenomenal strides in commercial operations throughout the world. Growth in major metropolitan areas has far exceeded expectations and is outstripping system capacity. If this trend continues, the effects of rapid growth will soon reach even the smallest markets. The predominant problem with respect to continued growth is that the customer base is expanding while the amount of electromagnetic spectrum allocated to cellular service providers for use in carrying radio frequency communications remains fixed. Innovative solutions are required to meet these increasing capacity needs in the limited available spectrum as well as to maintain high quality service and avoid rising prices.

Currently, channel access is primarily achieved using Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA) methods. In frequency division multiple access systems, a communication channel comprises a single radio frequency band into which the transmission power of a signal is concentrated. In time division multiple access systems, a communications channel comprises a time slot in a periodic train of time intervals over the same radio frequency. Although satisfactory performance is being obtained from FDMA and TDMA communications systems, channel congestion due to increasing customer demand commonly occurs. Accordingly, alternate channel access methods are now being proposed, considered and implemented.

Spread spectrum comprises a communications technique that is finding commercial application as a new channel access method in wireless communications. Spread spectrum systems have been around since the days of World War II. Early applications were predominantly military oriented (relating to smart jamming and radar). However, there is an increasing interest today in using spread spectrum systems in communications applications, including digital cellular radio, land mobile radio, and indoor/outdoor personal communication networks.

Spread spectrum operates quite differently from conventional TDMA and FDMA communications systems. In a direct sequence code division multiple access (DS-CDMA) spread spectrum transmitter, for example, a digital symbol stream at a basic symbol rate is spread to a transmit symbol rate (or chip rate). This spreading operation involves applying a user unique digital code (the spreading or signature sequence) to the symbol stream that increases its symbol rate while adding redundancy. This application typically multiplies the digital symbol stream by the digital code. The resulting transmitted data sequences (chips) are then modulated using an appropriate modulation scheme to generate an output signal. This output signal (referred to as a channel, such as a traffic channel or a pilot channel) is added to other similarly processed (i.e., spread) output signals (channels) for multi-channel transmission over a communications medium. The output signals of multiple users (channels) advantageously then share one transmission communica-

tions frequency, with the multiple signals appearing to be located on top of each other in both the frequency domain and the time domain. Because the applied digital codes are user unique, however, each output signal transmitted over the shared communications frequency is similarly unique, and through the application of proper processing techniques at the receiver may be distinguished from each other. In the DS-CDMA spread spectrum receiver, the received signals are demodulated and the appropriate digital code for the user of interest is applied (i.e., multiplied, or matched) to despread, or remove the coding from the desired transmitted signal and return to the basic symbol rate. Where this digital code is applied to other transmitted and received signals, however, there is no despread as the signals maintain their chip rate. The despreading operation thus effectively comprises a correlation process comparing the received signal with the appropriate digital code.

Before any radio frequency communications or information transfer between a base station and a mobile station of the spread spectrum communications system can occur, the mobile station must find and synchronize itself to the timing reference of that base station. In a direct sequence code division multiple access spread spectrum communications system, for example, the mobile station must find downlink chip boundaries, symbol boundaries and frame boundaries of this timing reference clock. The most common solution implemented to this synchronization problem has the base station periodically transmit (with a repetition period  $T_p$ ) on a pilot channel, and the mobile station detect and process, a recognizable pilot code  $\bar{c}_p$  of length  $N_p$  chips as shown in FIG. 1. In one type of CDMA communications system, each base station utilizes a different, known pilot code taken from a set of available pilot codes. In another type of CDMA communications system, each base station utilizes the same pilot code, with differences between base stations being identified through the use of differing phases for the transmissions.

In the spread spectrum receiver of the mobile station, the received signals are demodulated and applied to a filter matched to the pilot code(s). It is, of course, understood that alternate detection schemes, such as sliding correlation, may be used for pilot code processing. The output of the matched filter peaks at times corresponding to the reception times of the periodically transmitted pilot code. Due to the effects of multi-path propagation, several peaks may be detected relating to a single pilot code transmission. From processing these received peaks in a known manner, a timing reference with respect to the transmitting base station may be found with an ambiguity equal to the repetition period  $T_p$ . If the repetition period equals the frame length, then this timing reference may be used to frame synchronize mobile station and base station communications operation.

While any length of  $N_p$  in chips for the transmitted pilot code  $\bar{c}_p$  may be selected, as a practical matter the length of  $N_p$  in chips is limited by the complexity of the matched filter implemented in the mobile station receiver. At the same time, it is desirable to limit the instantaneous peak power  $\hat{P}_p$  of the pilot code signal/channel transmissions in order not to cause high instantaneous interference with other spread spectrum transmitted signals/channels. To obtain sufficient average power with respect to pilot code transmissions given a certain chip length  $N_p$ , it may become necessary in the CDMA communications system to utilize a pilot code repetition period  $T_p$  that is shorter than a frame length  $T_f$  for the pilot channel as illustrated in FIG. 2.

Another reason for transmitting multiple pilot codes  $\bar{c}_p$  within a single frame length  $T_f$  is to support inter-frequency